OAK RIDGE National Laboratory

NXS Neutron School Intro

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ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

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Safe operations is the **#1** priority

Safety notes & reminders

- Remember – neutron beams will activate samples & beamline components
- Read and obey all radiation safety postings
- If you are unsure stop and seek assistance

Celebrating 81 years at ORNL

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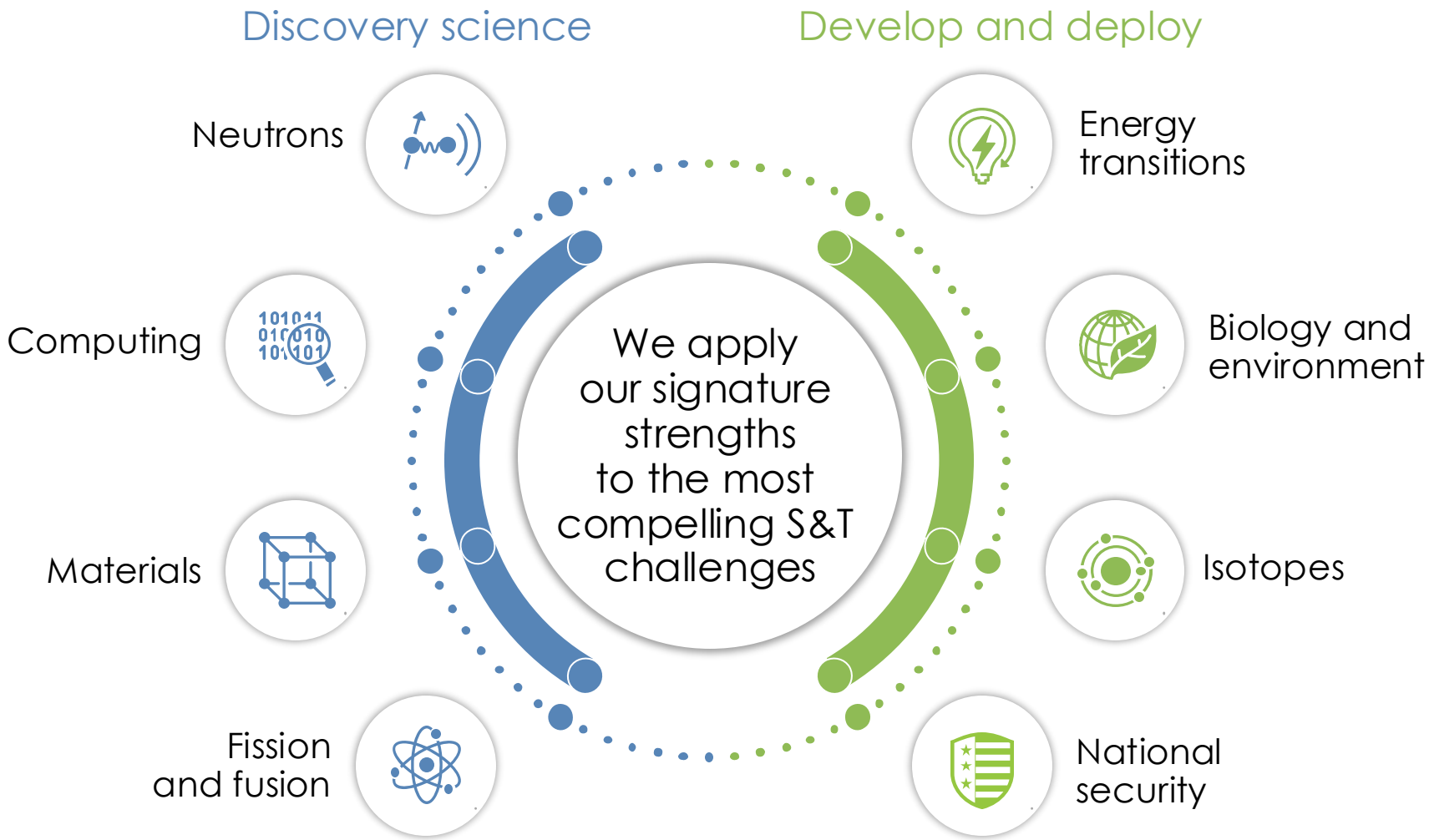
Neutron science is a critical part of ORNL's broad scientific portfolio



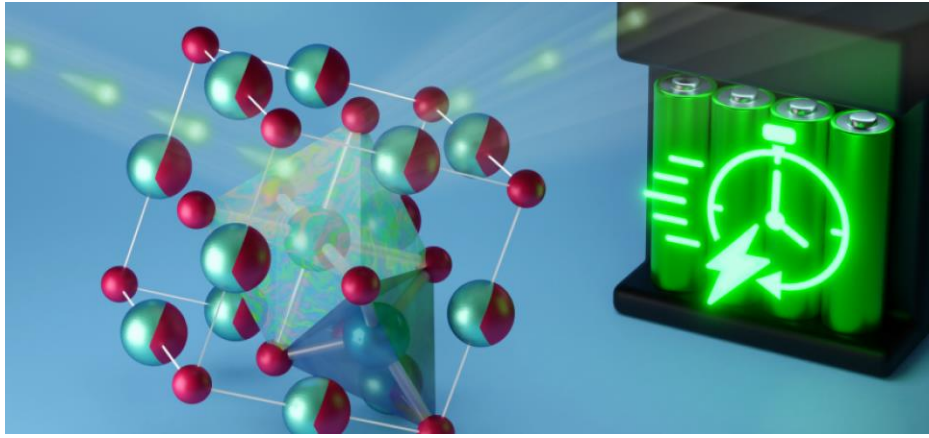
Neutron scattering was pioneered at ORNL

- The Graphite Reactor enabled the first neutron scattering experiments
- This groundbreaking work spurred ORNL's expansion in multiple scientific areas through the 1950s
  - Materials
  - Metallurgy: Radiation effects in metals
  - Environment: Genetics
  - Computing: Calculations for reactor shielding

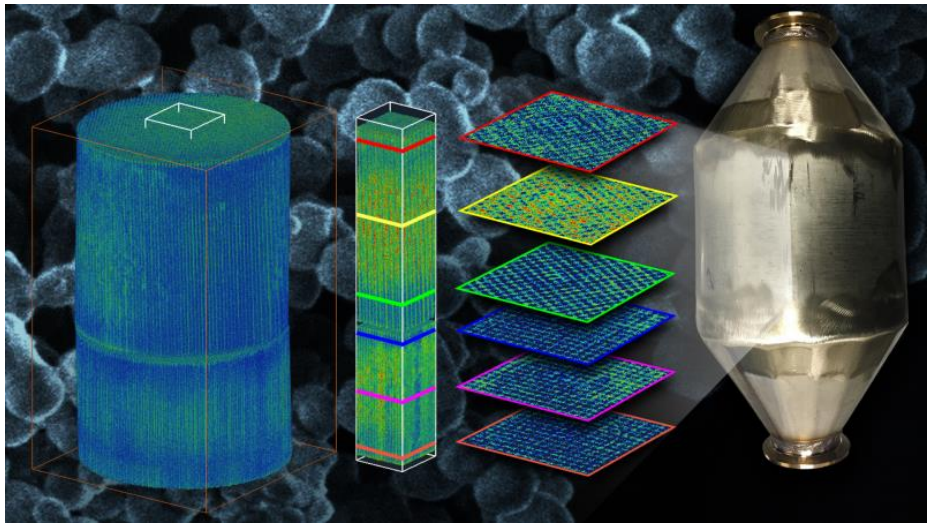
In 1994, Clifford Shull (right) received the Nobel Prize in Physics for the development of neutron scattering techniques at the Graphite Reactor

Why neutrons?

- Materials science research is key to addressing many of the world's most pressing problems
  - Carbon neutrality, quantum computing, human health/medicine, structural materials, energy storage and more
- Neutrons are a critical part of the materials science toolkit because they provide:
  - Unique strengths (contrast, penetration, sensitivity to light elements and to energy changes, magnetism)
  - The diversity needed to adapt to changing needs
  - Answers to important questions that cannot be obtained any other way: "We solve problems that nobody else can"



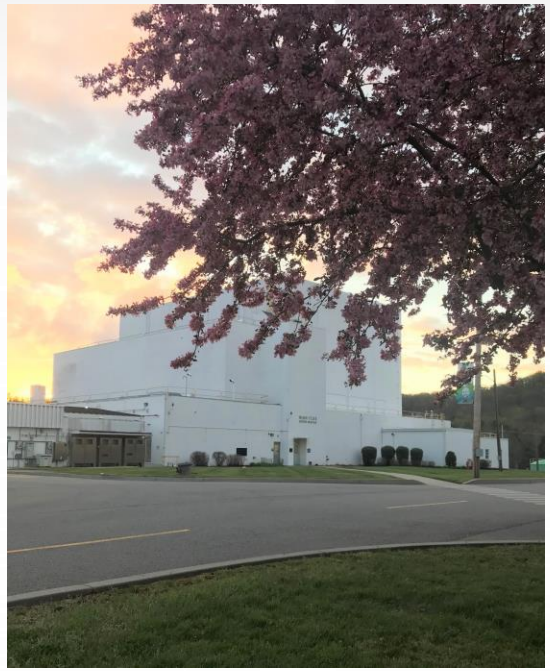
Above, a cousin of table salt could make energy storage faster and safer. (*Nature*, Sept. 2, 2020, "A disordered rock salt anode for fast-charging lithium-ion batteries") Below, add-on device makes home furnaces safer, cleaner and longer-lasting with acidic gas reduction (AGR). In 2022, the ORNL AGR technology received a coveted R&D 100 award and was selected for targeted investment through ORNL's Technology Innovation Program.



SNS & HFIR: Two world-leading user facilities

Spallation Neutron Source

- Nuclear spallation
  - 1.7MW Proton beam on mercury target
- 18 instruments in user program
  - One in commissioning
  - One beamline for NP
- A Pulsed source of neutrons
  - All instruments use time-of-flight
- Key technical strengths
  - High resolution, large bandwidth, thermal & epithermal neutrons
- World's brightest pulsed source



High Flux Isotope Reactor

- Nuclear fission
  - Highly-enriched U fuel
- 12 instruments in user program
- Continuous source
- Key technical strengths
  - Focusing optics, polarized neutrons, narrow bandwidth, parametric studies, thermal & cold neutrons
- World's brightest reactor source
  - Highest flux of thermal Neutrons

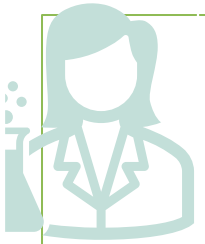
Neutron User Program statistics

30 instruments at 2 facilities

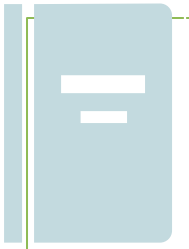
1500+ General User proposals submitted per year

356 unique HFIR users and 673 unique SNS users per year

2000+ total user visits across 1000+ experiments per year across both facilities



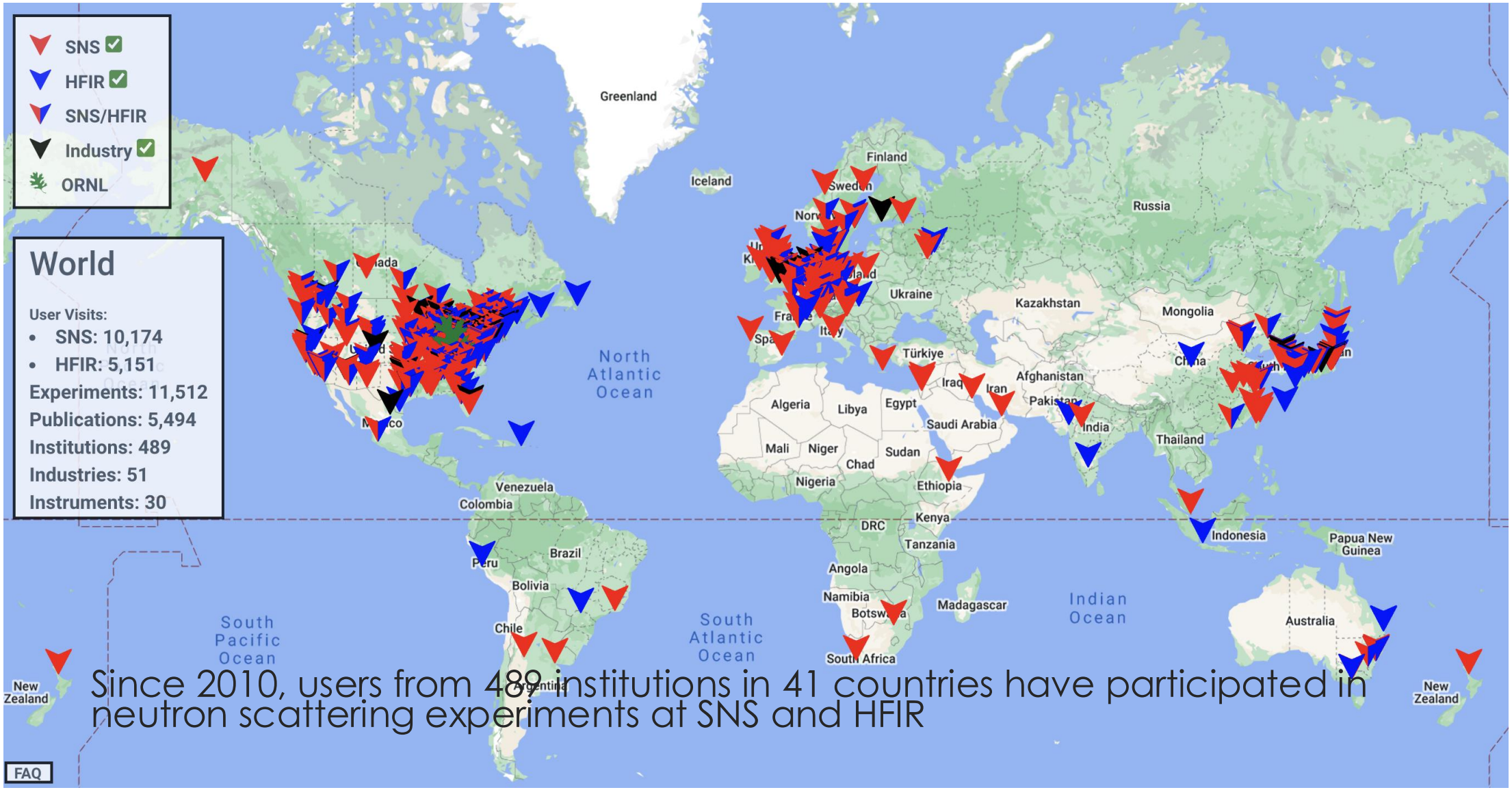
38% of users each year are new users



588 peer reviewed publications per year (424 are instrument publications)

Over 6,000 samples per year

Interactive user map displays worldwide user community



Since 2010, users from 489 institutions in 41 countries have participated in neutron scattering experiments at SNS and HFIR

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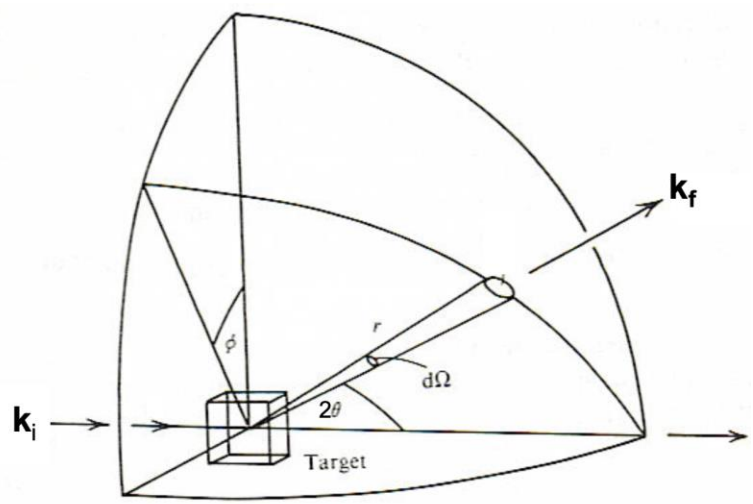
Neutron schools play an essential role

- Training
- Education
- Networking

Scattering Physics & Fourier Series

- Fourier transforms are essential for the mathematical frameworks used to describe scattering theory
  - Represent information in the frequency domain.
- Relates the real-space and reciprocal space representation of atoms
- Allows interpretation of measured cross sections
- Used to describe spatial and temporal correlation fucntions
- Fourier WebCam (https://ncnr.nist.gov/instruments/magik/calculators/fourier_webcam/)



$$\frac{d\sigma}{d\Omega} = \frac{\text{number of neutrons scattered per second into d}\Omega}{\Phi\ \text{d}\Omega}$$

$$\frac{\delta\sigma}{\delta\Omega} = \sum_{i,j} b_i b_j e^{i(k_i - k_j)(r_i - r_j)}$$

Fourier components of correlations between atoms

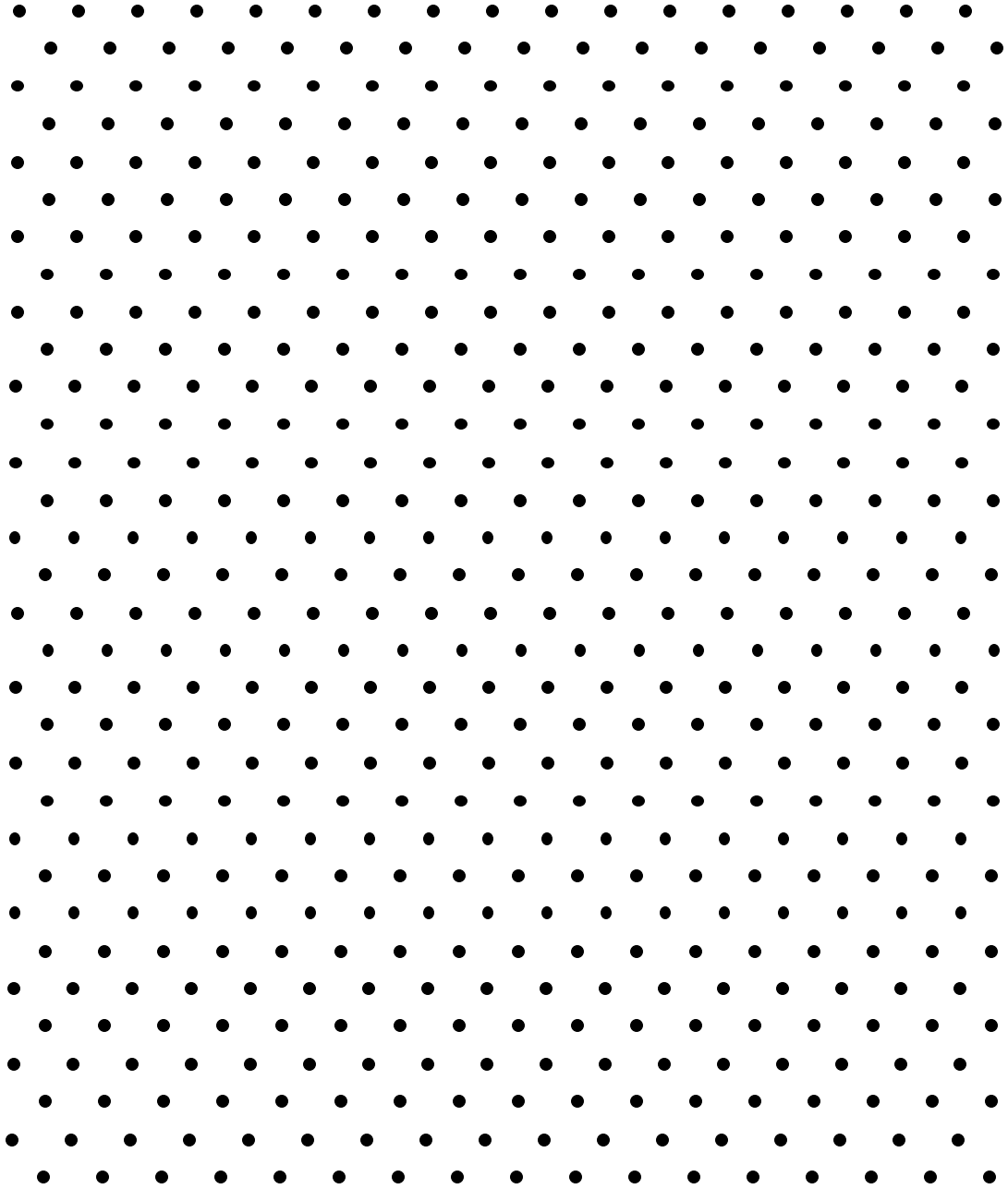
Some thoughts …

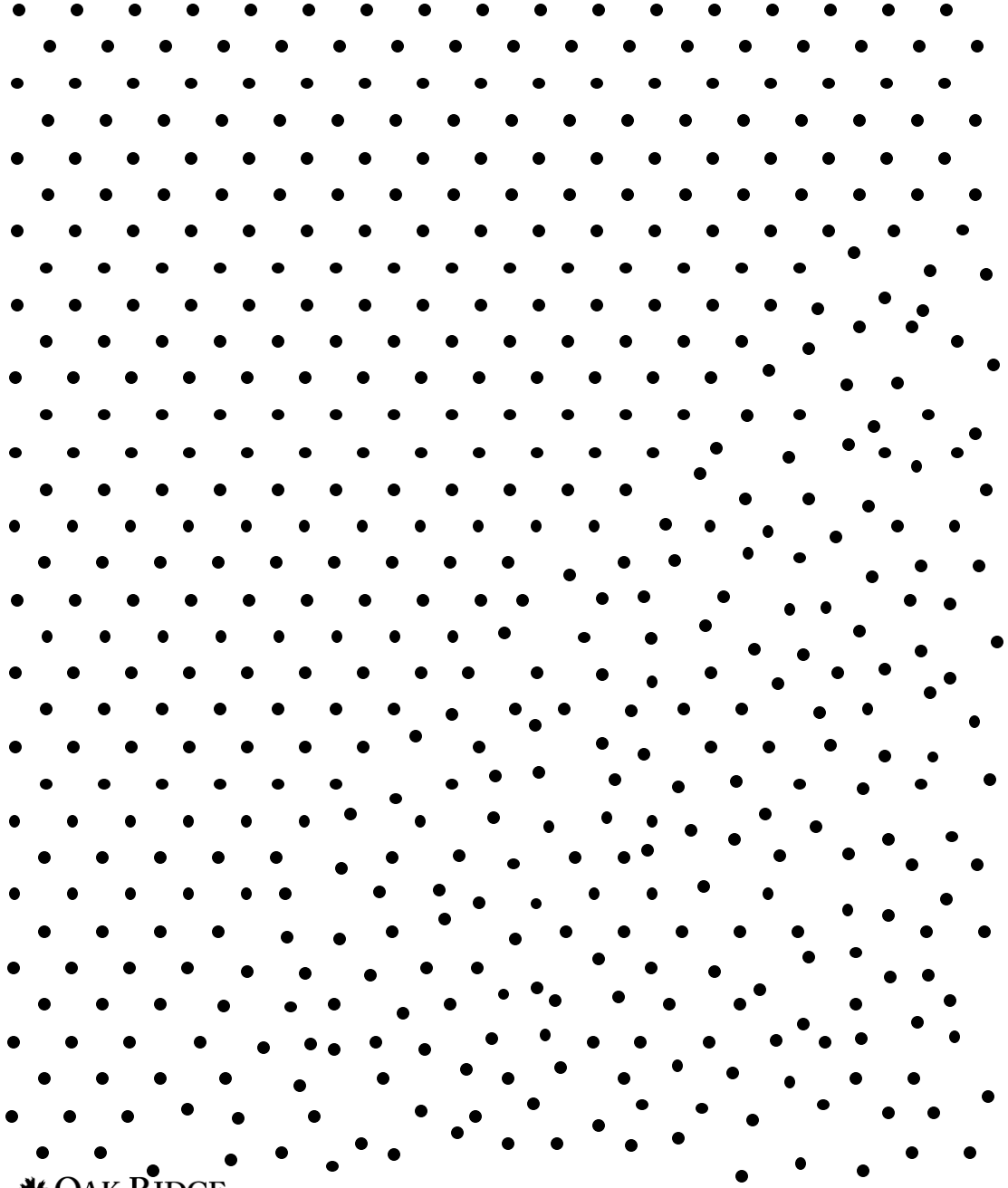
Ask Questions

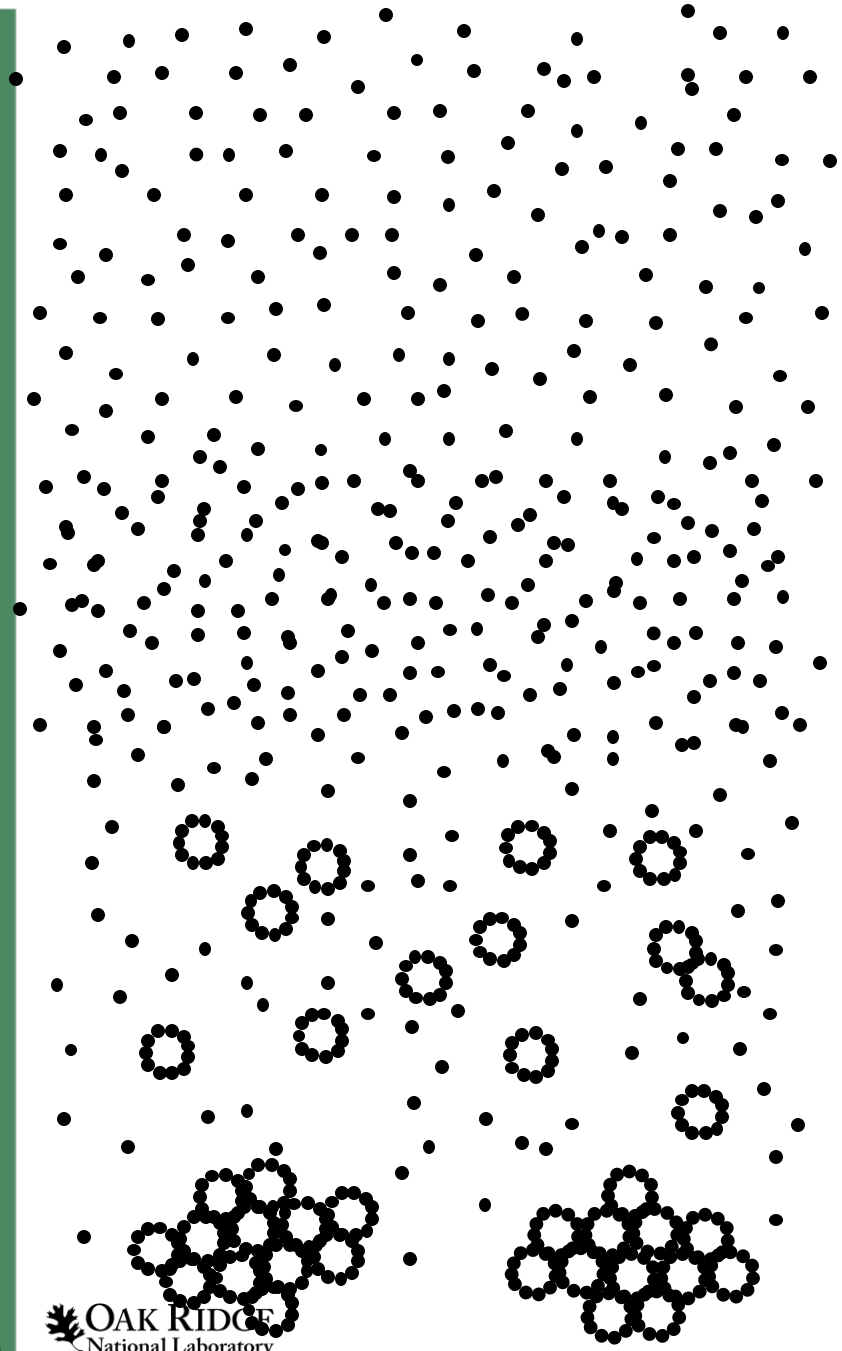
Be scientific – critically think about the experiment

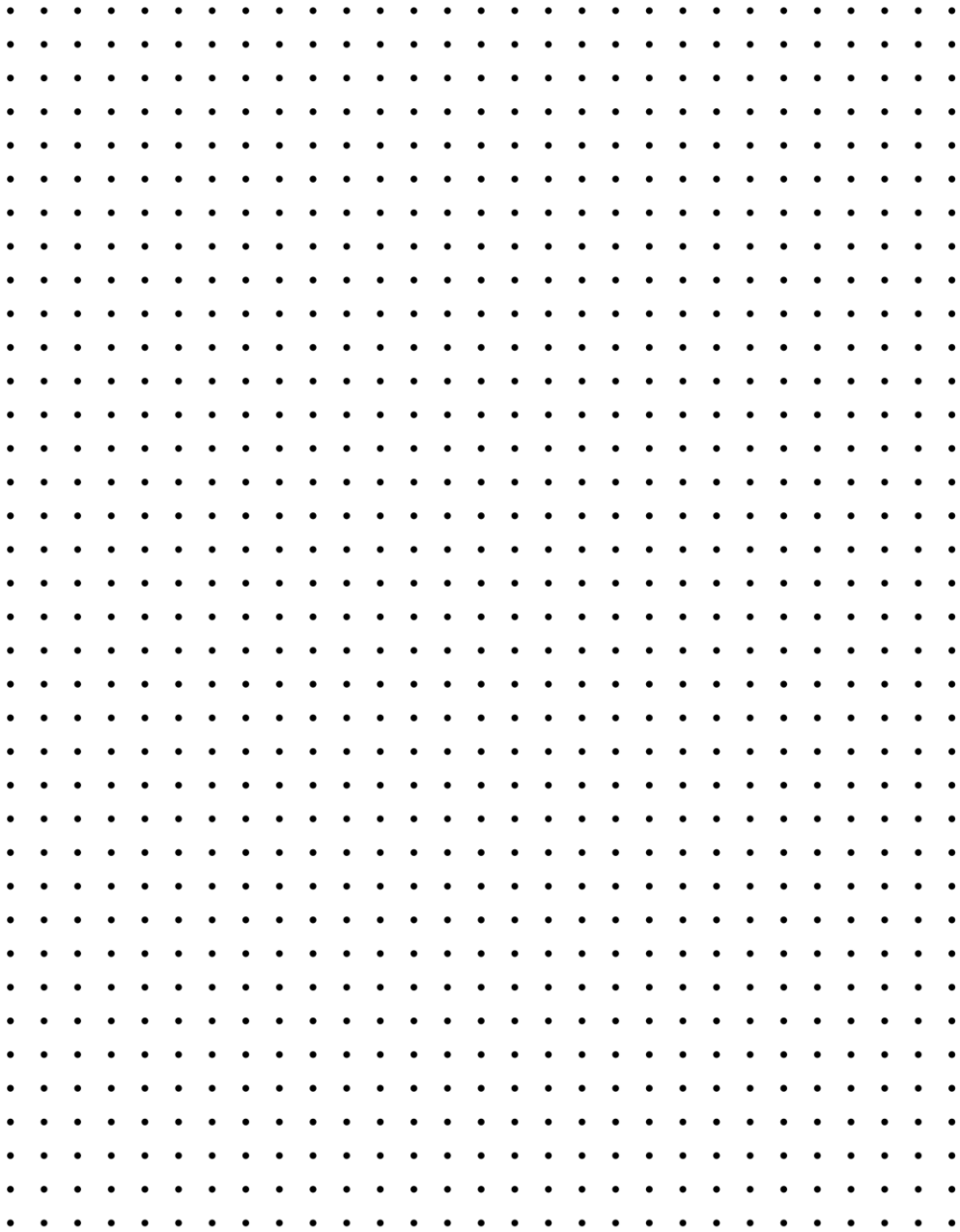
Sweat the data – errors and variance matter

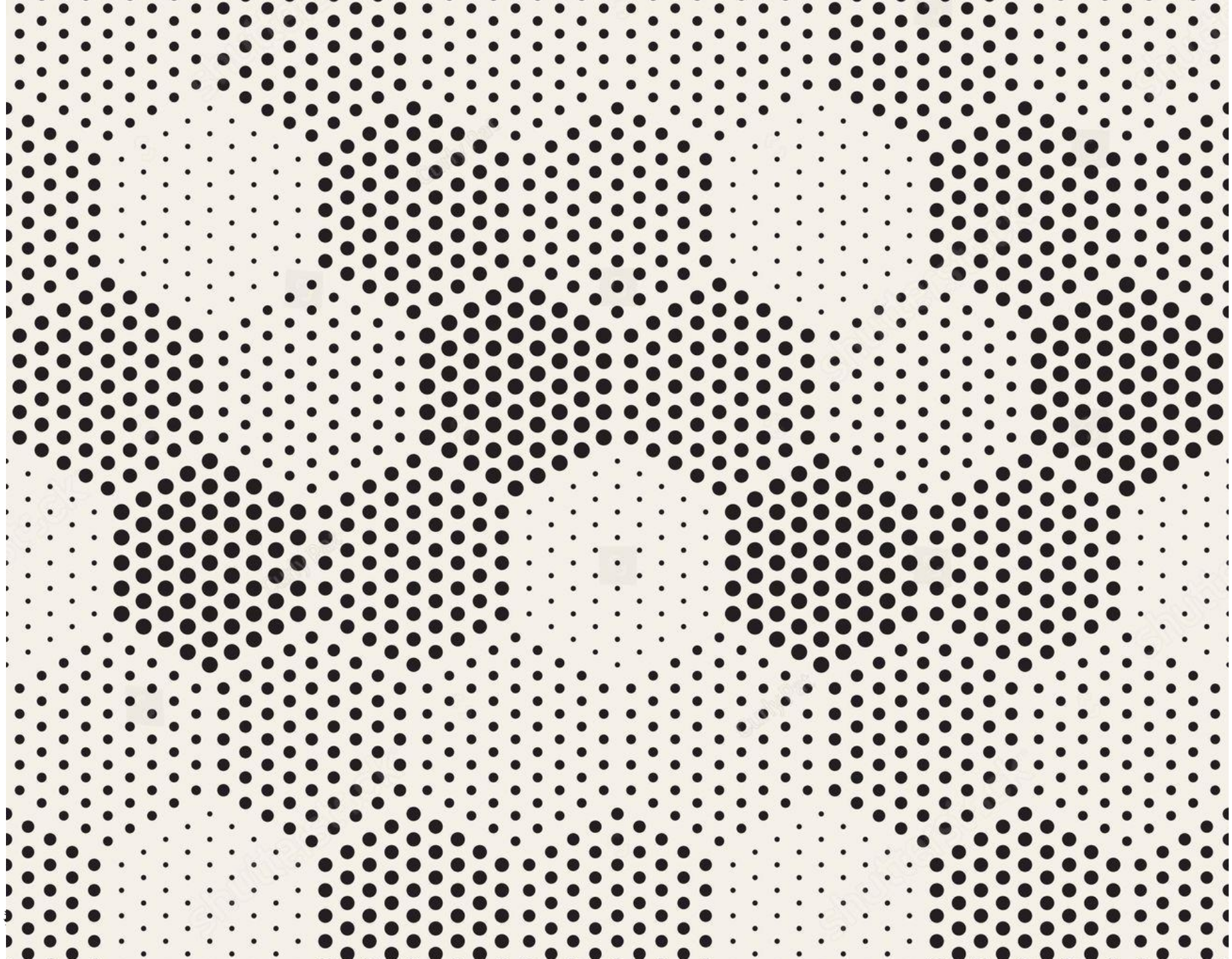
Enjoy, have fun, collaborate, discuss











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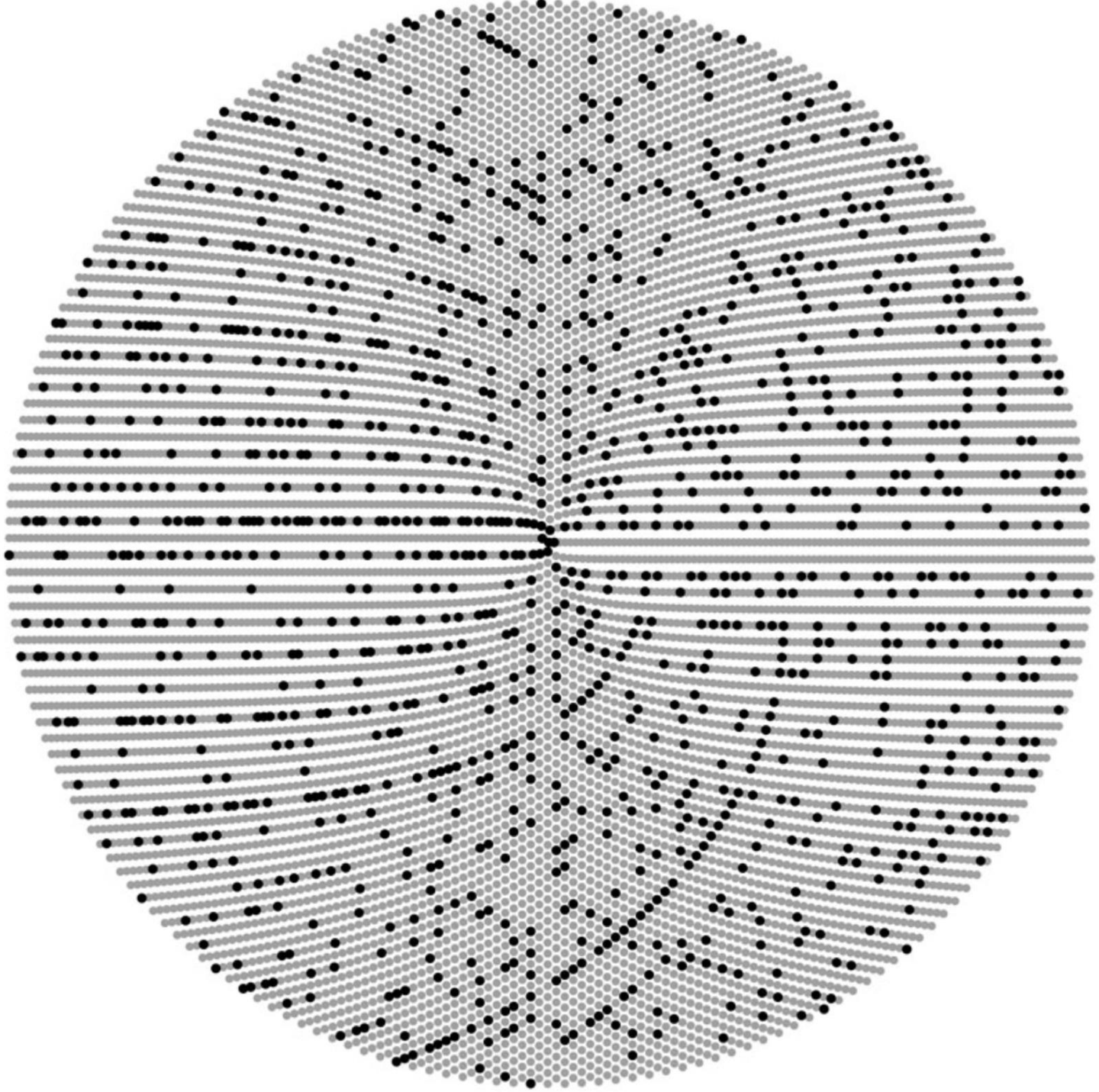

doi: 10.1126/science.z0p8ow7
Polar plot of prime number distributions